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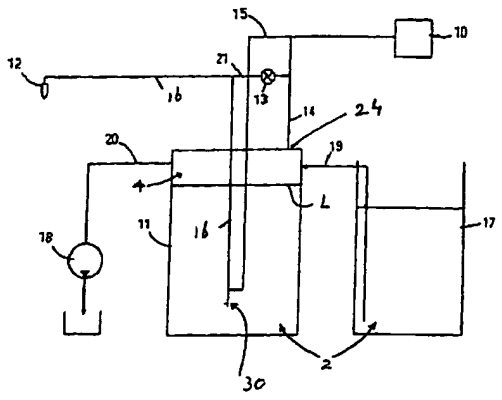
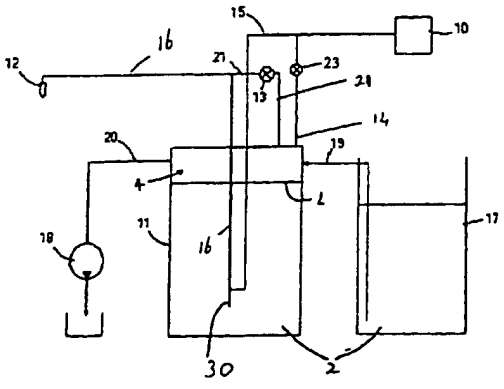
(54) Title: ABRASIVE FLUID JET SYSTEM





(57) Abstract: The invention provides an abrasive jet system having a high-pressure fluid supply (10) means supplying fluid to a vessel (11) which includes a layer of abrasive slurry and a top layer that contains substantially of fluid over the layer of abrasive slurry. The system also includes a first conduit (14) which leads from the fluid supply means to the top layer of fluid in the vessel and as high-pressure fluid is fed into the vessel, causes displacement of abrasive slurry from a discharge conduit (16). The system further includes a second conduit (21) which connects at different points to the first conduit and the discharge conduit, and including a fluid valve (13) between the operative connection to the first conduit and the discharge conduit, that controls the fluid flow within the second conduit. The fluid valve is closed once the system is pressurised to displace abrasive slurry through the discharge conduit (16) and is opened upon de-pressurization of the system to allow fluid flow from the first conduit (14) to the second conduit and to stop discharge of the abrasive slurry.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

ABRASIVE FLUID JET SYSTEM

Field of the invention

The present invention relates to an abrasive fluid jet cutting system and in particular although not solely to a system for supplying a pressurised slurry from a pressurised abrasive slurry containing vessel to an abrasive-jet nozzle(s) to enable cutting or other abrasive-fluid jet machining operations to be carried out.

Background and Prior Art

Abrasive fluid jet systems in the art are used in many applications where precision-cutting is required. An example of such an application is the singulation of substrates. One type of abrasive jet system utilizes abrasive that is stored and discharged under pressure from a pressure vessel to mix with the driving fluid immediately before the nozzle to form an abrasive slurry. Such mixing is achieved by a venturi effect. The slurry is normally then accelerated through a nozzle to form an abrasive fluid jet tool for cutting substrates.

Such existing systems require the separate and independent delivery of abrasive for each of the nozzles where a multi-nozzle cutting head is to be provided. Such independent delivery requires independent control and increases the chances of one or more nozzles of the multi-nozzle cutting head operating in a less than ideal condition.

An alternative configuration of mixing an abrasive with a fluid is for example shown in WO 95/29792. In the system of WO 95/29792, a pressure vessel is provided within which an abrasive and a fluid under pressure are able to mix prior to being delivered via a conduit to the nozzle.

As increasingly higher liquid pressures are being used to take advantage of the increases in cutting power, liquid compressibility becomes an important factor. When it is required to stop discharging abrasive slurry and depressurise the abrasive slurry pressure vessel to pause the operational process or to facilitate abrasive recharge, as a result of the high pressures generated, there remains within the pressure vessel a volume of compressed fluid. With conventional state of the art systems, as the compressed volume is de-pressurised its only route of escape is through the discharge conduit, the inlet of which is positioned within the slurry confinement. Hence a volume of slurry continues to be discharged giving rise to problems with nozzle blockages. Such blockage comes about because the discharged slurry is under a lower than normal operational pressure and lacks sufficient momentum to settle in the delivery pipe or nozzle in a manner to avoid blockage.

Such undesired discharge may for example occur if the slurry containment pressure vessel pressurising pump fails. Since the slurry in the pressure vessel is under high pressure and is compressed by the pump, upon failure of the pump the compressed slurry will expand and continue, for at least for a short period, to deliver the slurry through the delivery pipe to continue to discharge an abrasive slurry from the nozzle.

In designing a solution it is important to avoid problems, including high wear rates and reliability concerns brought about by the high pressures and the working medium itself which contains abrasives.

It is an object of the present invention to mitigate the above disadvantages and to avoid nozzle blockage or to provide the public with a useful choice.

Summary of the Invention

Accordingly in a first aspect the present invention consists in an abrasive fluid jet system comprising:

- a vessel including a layer of abrasive slurry and a top layer comprising substantially of fluid over the layer of abrasive slurry;
- a high-pressure fluid supply means to supply fluid to said vessel;
- a first conduit leading from the fluid supply means to the top layer of fluid in the vessel, to cause displacement of abrasive slurry from a discharge conduit as high-pressure fluid is fed into the vessel;
- a second conduit operatively connected at different points to the fluid flow of the first conduit and the abrasive slurry from the discharge conduit, said second conduit including a fluid valve between the operative connection to the first conduit and the discharge conduit which controls the fluid flow through the second conduit between the first conduit and the discharge conduit;

wherein the fluid valve is closed once the system is pressurised to displace abrasive slurry through the discharge conduit and the fluid valve is open upon de-pressurization of the system to allow fluid flow from the first conduit to the second conduit and to stop discharge of the abrasive slurry.

Preferably upon starting the system, the fluid valve is open to allow water flow through the second conduit to pressurise the system and the fluid valve is closed for operation of the fluid jet system once the vessel is sufficiently pressurised.

Preferably the high-pressure fluid supply means feeds fluid to the discharge conduit through a third conduit to produce a mixture of fluid together with the abrasive slurry for ejection through an ejection means, provided at the end of the discharge conduit.

Preferably a second fluid valve, provided in the first conduit is to control the flow of fluid from the high-pressure fluid supply means to the vessel.

Preferably it includes a hopper providing a supply of abrasive slurry to the vessel, and a pump for drawing fluid from the top layer of fluid in the vessel, wherein the resulting pressure caused by pumping fluid from the vessel draws abrasive slurry from the hopper into the vessel.

In a second aspect the present invention consists in an abrasive slurry pressurising system comprising

a pressure vessel defining a compartment within which there can be maintained an abrasive slurry volume and a fluid substantially absent of abrasive material volume above said abrasive slurry volume

a supply of abrasive mixture connectable to the compartment

a delivery conduit to deliver fluid under pressure to said compartment via a first opening of said pressure vessel defined by said delivery conduit

a slurry uptake and delivery conduit to deliver the slurry contents of compartment of said pressure vessel via a second opening of said pressure vessel defined by said slurry uptake and delivery conduit to a nozzle under the driving influence of the fluid under pressure entering said compartment via said first opening

a pressure control conduit in fluid connection with said fluid substantially absent of abrasive said pressure control conduit including a fluid flow control valve to regulate the pressure within said compartment.

Preferably said pressure control conduit is in fluid connection with said compartment via a third opening of said compartment, said third opening provided by said pressure control conduit and located to be within said fluid substantially absent from said abrasive.

Preferably said delivery conduit extends into said compartment to position said first opening to be within said abrasive slurry.

Preferably said pressure control conduit is in fluid connection with said compartment via said first opening, said first opening located to be within said fluid substantially absent from said abrasive.

Preferably said pressure control conduit is also in fluid connection with said slurry uptake and delivery conduit remote from said compartment to, when said fluid flow control valve is in a non closed condition, relieve pressure within said compartment via said nozzle.

Preferably said pressure control conduit includes an exhaust outlet remote from said compartment to, when said fluid flow control valve is in a non closed condition, relieve pressure within said compartment via exhaust outlet.

Preferably said fluid flow control valve is responsive to delivery conduit fluid pressure and if such is below a specified pressure corresponding to being below a desirable system operating pressure, said valve will be in a non closed condition.

Preferably fluid comprises predominantly of water.

Preferably said slurry comprises of a an abrasive material entrained within said fluid.

In a further aspect the present invention consists in a method of operating a system as herein before described comprising;

to said compartment containing said abrasive slurry and said fluid substantially absent from abrasive material above said abrasive slurry, delivery fluid under pressure via said delivery conduit, whilst allowing pressure relief from said compartment to occur via said pressure relief conduit by said fluid flow control valve being in a non closed condition

when a sufficient pressure is reached within said compartment to allow the nozzle to operate in a desired material cutting mode, closing said fluid flow control valve to then urge said pressure relief of said compartment to occur by the delivery of slurry via said slurry uptake and delivery conduit to said nozzle.

In still a further aspect the present invention consist in method of operating a system as herein before described comprising;

for a compartment containing said abrasive slurry and said fluid substantially absent from abrasive material above said abrasive slurry, and operating under pressure from fluid delivered via delivery conduit to thereby displace slurry from said compartment via said slurry uptake and delivery conduit to said nozzle

moving said fluid flow control valve to a non closed condition thereby preventing said displacement of slurry as the pressure within said compartment falls below a pressure to allow the displacement of said slurry via said slurry uptake and delivery conduit.

In still a further aspect the present invention consist in a method of controlling a system as herein before described comprising;

for a compartment containing said abrasive slurry and said fluid substantially absent from abrasive material above said abrasive slurry, and operating under pressure from fluid delivered via delivery conduit to thereby displace slurry from said compartment via said slurry uptake and delivery conduit to said nozzle

preventing said displacement of slurry if pressure within said compartment falls below a pressure to allow the nozzle to operate in a desired material cutting mode, by moving said fluid flow control valve to a non closed condition.
conduit to the second conduit and to stop discharge of the abrasive slurry.

In still a further aspect the present invention consist in an abrasive fluid jet system comprising:

a) a vessel having a compartment for carrying (a) a volume of abrasive slurry above which there is provided (b) a volume comprising of fluid substantially absent of abrasive slurry;
b) a high-pressure fluid supply means to supply fluid to said vessel;
c) a discharge conduit including an inlet opening to locate within said volume of abrasive slurry and a nozzle
d) a delivery conduit leading from the fluid supply means into said vessel to under as high-pressure fluid feed therethrough and into the vessel to induce flow of abrasive slurry into and through said discharge conduit to said nozzle;
e) a pressure relief conduit in fluid connection with said vessel to operatively connect between the volume comprising substantially of fluid and said discharge conduit, said pressure relief conduit including a fluid valve which controls the fluid flow therethrough

wherein the fluid valve in an opened condition induces relief of pressure from said vessel by establishing a flow alternative to said flow of (d) of fluid via said pressure relief conduit to said nozzle.

Brief description of the Drawings

Figure 1 is a system diagram illustrating a first embodiment of the invention.

Figure 2 is a system diagram illustrating a second embodiment of the invention.

Figure 3 is a system diagram illustrating a third embodiment of the invention.

Figure 4 is a system diagram illustrating a fourth embodiment of the invention.

Detailed Description of the Preferred Embodiments of the Invention

The present invention relies on the natural tendency for fluid to take the path of least resistance to enable compressed fluid volume to be released into a discharge conduit with the design being such that the discharge is absent of abrasive.

With reference to Figure 1 which is a diagram illustrating a first embodiment of the invention, there is provided a pressure vessel 11 which provides a compartment for retaining an abrasive slurry. An abrasive slurry is a mixture of an abrasive material which is entrained within a fluid such as for example water or a liquid composition containing water. The vessel 11 contains the abrasive slurry 2 above which a layer of liquid 4 is provided. This liquid 4 is the same liquid used to entrain the abrasive particles to provide the slurry but which above a certain level "L" in the vessel is not mixed with abrasive.

A source of pressurised fluid 10 which incorporates a pressurising pump feeds fluid to the vessel 11. Feeding of fluid from the source 10 is through delivery conduits 14 and 15. Conduit 15 is provided to deliver fluid to the uptake and delivery conduit to thereby provide the appropriate dilution to the slurry being displaced through the opening 30. This dilution may be necessary to avoid blockage of the uptake and delivery conduit.

Conduit 14 is the main delivery and vessel pressurising conduit. In the configuration of the invention shown in figure 1, the conduit 14 has its outlet opening 24, defining a first opening in the vessel 11 within the fluid only region of the pressure vessel (ie above L)

A hopper 17 feeds abrasive slurry 2 to the vessel 11 through conduit 19.

A pressure relief conduit 21 is provided to be in fluid communication with the volume in vessel and be in flow contact with the fluid absent of abrasive. In the configuration of figure 1, the flow contact is provided via part of said delivery conduit 14. A fluid valve 13 controls the flow of fluid across pressure control conduit 21.

In normal operation of the system the pump system delivers pressurised fluid to the vessel and this causes the displacement of abrasive slurry 2 via the inlet opening 30 of the slurry uptake and delivery conduit 16 to nozzle 12. The inlet opening is positioned below L and preferably near the bottom of the vessel 11.

The pressure relief conduit 21 can be considered a by pass conduit to by pass the flow of volume of the vessel which contains abrasive. The control of the bypass achieved by a fluid flow control valve which is closable to close the conduit 21.

In the configuration of Figure 1, the conduit 14 is connected to the top of the vessel 11 where there is no abrasive 2 present. On depressurisation (when for example

the fluid source 10 fails, is or is about to be turned off) the fluid valve 13 connecting conduit 21 to the delivery conduit outside of the vessel is opened. The volume of the content inside the vessel 11 will remain compressed but will wish to expand. Two openings are available but such expansion will have a preference to discharge through conduit 21, instead of through the opening 30 of the delivery conduit 16. This is because expansion of the volume by displacement of slurry flow through the opening 30 of the conduit 16 whose internal diameter, length and most predominantly because of the density and viscosity of the slurry bed 2 leads to a higher flow resistances.

On start-up and pressurisation of the system, fluid valve 13 will initially be open. The fluid will flow from source 10 into the vessel 11 through conduit 14. With fluid valve 13 open some of the fluid flow will enter conduit 21. Pressurisation of the vessel will also occur but this is reduced because of the partial flow diversion. In the preferred form where the pressure relief conduit is connected to the slurry uptake and delivery conduit upstream of the second opening 30 (and preferably outside of said vessel) the combination of resistance of slurry flow up through the opening 30 and the fact that the flow of fluid through the conduit 21 and into the uptake and delivery conduit creates a back pressure in that part of the uptake and delivery conduit towards the opening 30, no slurry will travel to the nozzle. Upon closing of the valve 13 there will then be sufficient mass flow into the slurry pressure vessel 11 to cause a displacement of abrasive into the inlet opening 30 of conduit 16.

With valve 13 closed, the fluid flow from source 10 enters the vessel 11 through conduit 14 thus causing displacement of abrasive slurry into the inlet opening 30 of the uptake and delivery conduit 16 where it mixes with the main flow from conduit 15 and is carried to the nozzle through the uptake and delivery conduit 16 to the nozzle 12.

Abrasive flow can also at any time be halted by opening valve 13. On de-pressurisation, fluid valve 13 is open to provide an alternative and preferred route through conduit 21 for the compressed fluid. Upon expansion of the contents in the vessel such expansion is via the relief conduit 21. As conduit 14 has its opening in the vessel above level L, which ensures that the abrasive slurry is able to reach fluid valve 13 and it hence normally operates on clean water and with a minimal pressure differential hence its service life-time will be generally higher than would otherwise be the case. In addition the inner diameter of conduit 21 should be sufficiently large to ensure that the velocity of the escaping fluid is well below the settling velocity of the abrasive slurry 2 used. In this way any abrasive particles in the vessel above Level "L" will further be prejudiced not to enter or travel along the conduit 14 and enter the conduit 21 through the fluid valve 13.

Figure 2 illustrates a second embodiment of the invention where a separate relief conduit 21 is provided. Unlike the first embodiment shown in Figure 1, conduit 21 is not connected to conduit 15, and serves purely as a route of escape for the compressed volume in vessel 11. The second fluid valve 23 always operates on clean fluid, and the fluid valve 13 operates less frequently, ie. only at pressurisation and depressurisation stages. As a result, wear on valve 13 is decreased. The provision of the second fluid valve 23 is preferred but not essential.

In situation where a flow diversion is required when the pump pressurising the source 10 fails, a loss in pressure in the conduit 14 or at the pump may be detected by a pressure sensor thereby automatically opening valve 13 to provide pressure relief within the vessel through the conduit 21. In situation where the flow of abrasive slurry is desired to be stopped but where the pump pressurising the source 10 continues to operate, the valve 13 may merely be opened and fluid may continue to flow into the vessel 11 through the conduit 14 and 15 (if this is not separately closed) but since the path of least resistance of the pressurised material within the vessel is through the conduit 21, water will enter and merely exit above L thereby ensuring only water will exhaust through the conduit 21 out towards the

nozzle 12. This flow will continue as long as the pump pressurising at the fluid source 10 continues to operate, the equilibrium of pressure of the compressed fluid is not reach and the valve 13 remains open.

A diaphragm pump 18 is used to draw fluid 4 from conduit 20, which creates a pressure in vessel 11 which in turn draws in abrasive slurry 2 from hopper 17 to vessel 11. In the particular embodiment in Figure 2, with fluid valve 13 and second fluid valve 23 closed, the diaphragm pump 18 is used to withdraw fluid through conduit 20 from the vessel creating a vacuum to draw in abrasive slurry 2 from the hopper 17 through conduit 19.

It would be appreciated that the system avoids fluid compressibility problems leading to unwanted discharging of abrasives to the nozzle at system pressurising and depressurising states. By providing an alternative route of less resistance for expansion of the compressed fluid volume from within the vessel from a point where no abrasive is carried to the nozzle and so the invention helps prevent nozzle blockages.

With reference to Figure 3, an alternative configuration is shown wherein the delivery conduit is positioned to have the first opening submerged in the slurry. In this configuration a separate opening provided by the pressure relief conduit is required to be positioned above L. The provision of the first opening 24 near the second 30 is that better mixing of the abrasive with the water to form the slurry is achieved nearer the second opening.

A further alternative is shown in figure 4 wherein the pressure relief conduit exhausts not into the uptake and delivery conduit but to a different location. This is a less preferred option in that the pressure from the fluid in the conduit 21 can not be used to provide a back pressure to fluid in the uptake and delivery conduit 16 and hence some slurry (during expansion in volume of the contents of the vessel) may travel into the uptake and delivery conduit through the opening.

The invention described herein is susceptible to variations, modifications and/or additions other than those specifically described and it is to be understood that the invention includes all such variations, modifications and/or additions which fall within the spirit and scope of the above description.

CLAIMS

1. An abrasive fluid jet system comprising:
   - a vessel including a layer of abrasive slurry and a top layer comprising substantially of fluid over the layer of abrasive slurry;
   - a high-pressure fluid supply means to supply fluid to said vessel;
   - a first conduit leading from the fluid supply means to the top layer of fluid in the vessel, to cause displacement of abrasive slurry from a discharge conduit as high-pressure fluid is fed into the vessel;
   - a second conduit operatively connected at different points to the fluid flow of the first conduit and the abrasive slurry from the discharge conduit, said second conduit including a fluid valve between the operative connection to the first conduit and the discharge conduit which controls the fluid flow through the second conduit between the first conduit and the discharge conduit;

   wherein the fluid valve is closed once the system is pressurised to displace abrasive slurry through the discharge conduit and the fluid valve is open upon de-pressurization of the system to allow fluid flow from the first conduit to the second conduit and to stop discharge of the abrasive slurry.

2. An abrasive fluid jet system according to claim 1, wherein upon starting the system, the fluid valve is open to allow water flow through the second conduit to pressurise the system and the fluid valve is closed for operation of the fluid jet system once the vessel is sufficiently pressurised.

3. An abrasive fluid jet according to claim 1 and 2, wherein the high-pressure fluid supply means feeds fluid to the discharge conduit through a third conduit to produce a mixture of fluid together with the abrasive slurry for ejection through an ejection means, provided at the end of the discharge conduit.

4. An abrasive fluid jet system according to any one of the preceding claims, wherein a second fluid valve, provided in the first conduit is to control the flow of fluid from the high-pressure fluid supply means to the vessel.

5. An abrasive fluid jet system according to any one of the preceding claims, which includes a hopper providing a supply of abrasive slurry to the vessel, and a pump for drawing fluid from the top layer of fluid in the vessel, wherein the resulting pressure caused by pumping fluid from the vessel draws abrasive slurry from the hopper into the vessel.

6. An abrasive slurry pressurising system comprising

a pressure vessel defining a compartment within which there can be maintained an abrasive slurry volume and a fluid substantially absent of abrasive material volume above said abrasive slurry volume

a supply of abrasive mixture connectable to the compartment

a delivery conduit to deliver fluid under pressure to said compartment via a first opening of said pressure vessel defined by said delivery conduit

a slurry uptake and delivery conduit to deliver the slurry contents of compartment of said pressure vessel via a second opening of said pressure vessel defined by said slurry uptake and delivery conduit to a nozzle under the driving influence of the fluid under pressure entering said compartment via said first opening

a pressure control conduit in fluid connection with said fluid substantially absent of abrasive said pressure control conduit including a fluid flow control valve to regulate the pressure within said compartment.

7. A abrasive slurry pressurising system as claimed in claim 7 wherein said pressure control conduit is in fluid connection with said compartment via a third opening of said compartment, said third opening provided by said pressure control conduit and located to be within said fluid substantially absent from said abrasive.

8. A abrasive slurry pressurising system as claimed in claim 7 wherein said delivery conduit extends into said compartment to position said first opening to be within said abrasive slurry.

9. A abrasive slurry pressurising system as claimed in claim 7 wherein said pressure control conduit is in fluid connection with said compartment via said first opening, said first opening located to be within said fluid substantially absent from said abrasive.

10. A abrasive slurry pressurising system as claimed in any one of claims 7 to 9 wherein said pressure control conduit is also in fluid connection with said slurry uptake and delivery conduit remote from said compartment to, when said fluid flow control valve is in a non closed condition, relieve pressure within said compartment via said nozzle.

11. A abrasive slurry pressurising system as claimed in any one of claims 7 to 9 wherein said pressure control conduit includes an exhaust outlet remote from said compartment to, when said fluid flow control valve is in a non closed condition, relieve pressure within said compartment via exhaust outlet.

12. A abrasive slurry pressurising system as claimed in any one of claims 7 to 11 wherein said fluid flow control valve is responsive to delivery conduit fluid pressure and if such is below a specified pressure corresponding to being below a desirable system operating pressure, said valve will be in a non closed condition.

13. A abrasive slurry pressurising system as claimed in any one of claim 7 to 12 wherein fluid comprises predominantly of water.

14. A abrasive slurry pressurising system as claimed in any one of claim 7 to 13 wherein said slurry comprises of a an abrasive material entrained within said fluid.

15. A method of operating a system as claimed in any one of claims 7 to 14 comprising;

to said compartment containing said abrasive slurry and said fluid substantially absent from abrasive material above said abrasive slurry, delivery fluid under pressure via said delivery conduit, whilst allowing pressure relief from said compartment to occur via said pressure relief conduit by said fluid flow control valve being in a non closed condition

when a sufficient pressure is reached within said compartment to allow the nozzle to operate in a desired material cutting mode, closing said fluid flow control

valve to then urge said pressure relief of said compartment to occur by the delivery of slurry via said slurry uptake and delivery conduit to said nozzle.

16. A method of operating a system as claimed in any one of claims 7 to 14 comprising;

for a compartment containing said abrasive slurry and said fluid substantially absent from abrasive material above said abrasive slurry, and operating under pressure from fluid delivered via delivery conduit to thereby displace slurry from said compartment via said slurry uptake and delivery conduit to said nozzle

moving said fluid flow control valve to a non closed condition thereby preventing said displacement of slurry as the pressure within said compartment falls below a pressure to allow the displacement of said slurry via said slurry uptake and delivery conduit.

17. A method of controlling a system as claimed in any one of claims 7 to 14 comprising;

for a compartment containing said abrasive slurry and said fluid substantially absent from abrasive material above said abrasive slurry, and operating under pressure from fluid delivered via delivery conduit to thereby displace slurry from said compartment via said slurry uptake and delivery conduit to said nozzle

preventing said displacement of slurry if pressure within said compartment falls below a pressure to allow the nozzle to operate in a desired material cutting mode, by moving said fluid flow control valve to a non closed condition.
conduit to the second conduit and to stop discharge of the abrasive slurry.

18. An abrasive fluid jet system comprising:

a) a vessel having a compartment for carrying (a) a volume of abrasive slurry above which there is provided (b) a volume comprising of fluid substantially absent of abrasive slurry;

b) a high-pressure fluid supply means to supply fluid to said vessel;

c) a discharge conduit including an inlet opening to locate within said volume of abrasive slurry and a nozzle;

d) a delivery conduit leading from the fluid supply means into said vessel to under as high-pressure fluid feed therethrough and into the vessel to induce flow of abrasive slurry into and through said discharge conduit to said nozzle;

e) a pressure relief conduit in fluid connection with said vessel to operatively connect between the volume comprising substantially of fluid and said discharge conduit, said pressure relief conduit including a fluid valve which controls the fluid flow therethrough

f) wherein the fluid valve in an opened condition induces relief of pressure from said vessel by establishing a flow alternative to said flow of (d) of fluid via said pressure relief conduit to said nozzle.

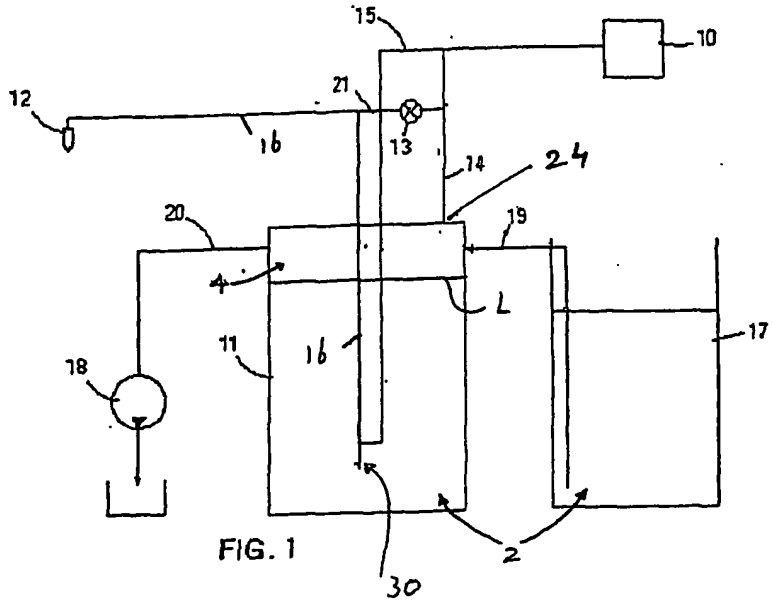
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FIG. 1

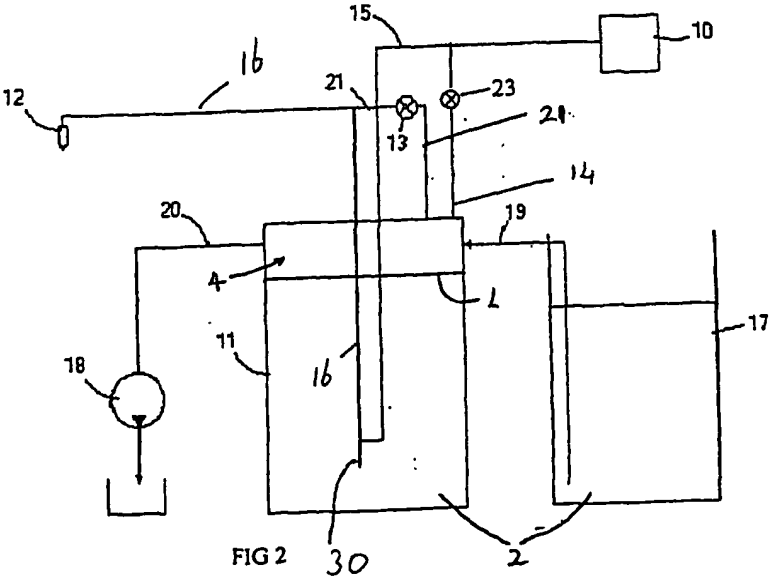
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FIG 2

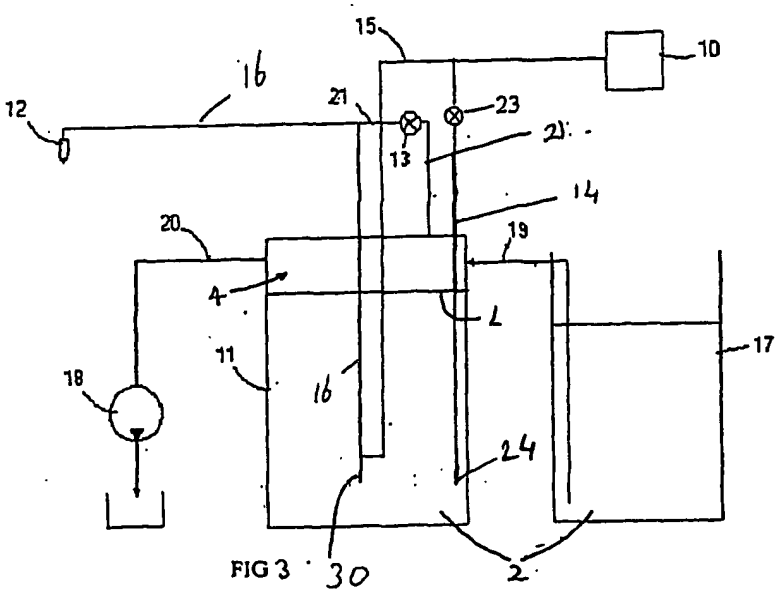
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FIG 3

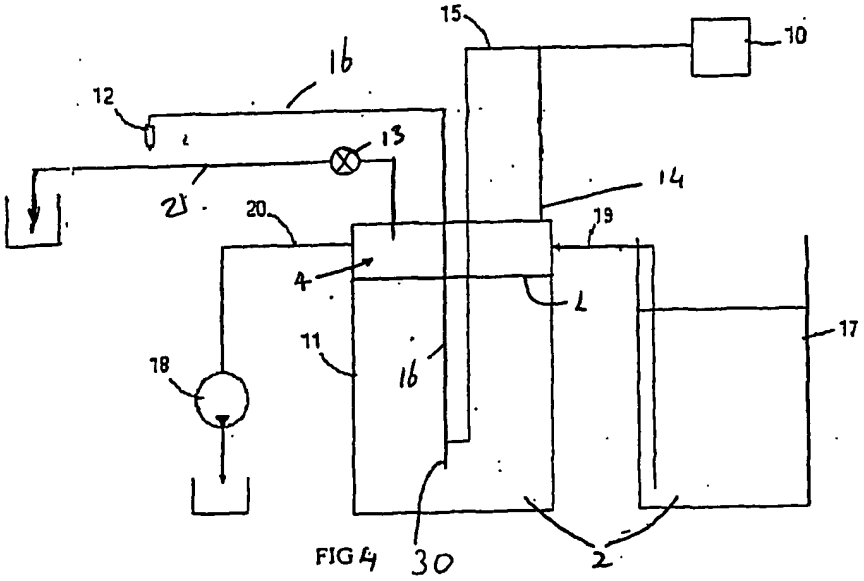
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FIG 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG 02/00065

CLASSIFICATION OF SUBJECT MATTER

IPC[7]: B24C 7/00, 1/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC[7]: B24C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 00/52679 A2 (B.H.R: Group Ltd.) 8 September 2000 (08.09.00) *figur 1; abstract.*	1,6,18
A	US 2667015 A (Berg) 26 January 1954 (26.01.54) *figur 1; column 4, lines 5-18.*	1,6,18

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

Information a patent family members

International application No.
PCT/SG 02/00065-0

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US A 2667015		none	
WO A 052679		none	